MAGNET SYSTEM (WBS 1.1)

i. Overview

The magnet system of the collider consists primarily of the superconducting dipole and quadrupole magnets for guiding and focusing the counter-circulating ion beams into well-defined orbits in the regular arcs of the machine lattice, as well as a large complement of special magnets ("insertion magnets") required for steering the beams into collisions at the six interaction points where the highly charged ion beams interact.

The magnet system is designed to allow operation in the energy range corresponding to a $B\rho$ from 97 to 840 T·m. Operation with either equal or unequal ion species in the colliding beams is required, imposing a ratio of up to 2.5:1 in the magnetic fields of the two rings. The superconducting magnets are optimized for heavy ion (in particular ^{197}Au) operation, with beam energies between 30 and 100 GeV/u. Operation above 100 GeV/u corresponding to 3.458 T in the arc dipoles might be possible.Besides reaching fields with substantial margins above the required field range, all of the RHIC magnets must meet stringent requirements on field quality, reproducibility, and long-term reliability. Existing technology was being used for the magnet design and construction, measuring and analysis procedures, cooling method, quench protection, instrumentation, and quality control standards. Improvements that were developed and tested during the R&D phase were incorporated into designs and fabrication methods.

The RHIC magnet lattice is designed to fit into the existing tunnel of ~3.8 km circumference. The lattice is divided into 6 arcs and 6 insertions for each of the two rings. In the arcs, the rings are separated radially by 90 cm. In the two rings of the collider, there are 408 dipoles, 492 quadrupoles, 72 trim quadrupoles, 288 sextupoles, and 492 magnets for correction of field perturbations. Table 1-1 gives the RHIC magnet inventory.

The field quality of accelerator magnets is characterized by normal and skew field harmonics, b_n and a_n, which are quoted in "primed units" and can be defined in terms of the field at the reference radius R which is taken as ~2/3 of the inner coil radius (i.e. R is 25 mm for the 80 mm aperture dipoles and quadrupoles, 40 mm for the 130 mm aperture quadrupoles, 31 mm for the 100 mm aperture dipoles and 67 mm for the 200 mm aperture dipole. The horizontal and vertical field components, B_x and B_y, throughout the magnet aperture are then given in polar coordinates (r, θ) by

$$B_y + i\ B_x = 10^{-4}\, B\,(R) \sum_{n=0}^{\infty} \left(b_{n'} + i\ a_{n'}\right)(\cos\ n\theta + \mathrm{i}\ \sin\ n\theta)\left(\frac{\mathrm{r}}{\mathrm{R}}\right)^{\mathrm{n}}$$

where i is the imaginary unit and $B\ (R)$ is the magnitude of the field due to the *fundamental* at the

$$B_x\,(x) = 10^{-4}\ B\,(R) \sum_n a_{n'} (x/R)^n$$

reference radius. The field components on the median plane (i.e. θ = 0) follow as

$$B_y\,(x) = 10^{-4}\, B\,(R) \sum_n b_{n'} (x/R)^n$$

In a normal dipole, $b_{0'} = 10^4$ and $B\ (R) = B_0$. In a normal quadrupole, $b_{1'} = 10^4$ and $B\ (R) = GR$ where G is the gradient $\partial B_y\ /\partial\ x$ at the magnet center. In general, for a 2 (m+1)-pole magnet $b_{m'} = 10^4$ and

$$B\,(R) = \frac{R^m}{m!}\left(\frac{\partial^m B_y}{\partial\, x^m}\right)_{x=0}$$

Magnet Nomenclature

A naming convention has been established for the various types of magnets to facilitate record keeping and physical tracking:

- Each cold mass will be named as indicated in the "Magnet/Cold Mass" Table 1-2. When a single cold mass is installed in a cryostat, the resulting magnet will be identified with the name of the cold mass inside.
- When several cold masses are combined as a cold mass assembly in a cryostat (the assembly magnets: CQS, CQT, etc) the resulting magnet will be identified as shown in the "Assembly" Table 1-3.

Table 1-1. RHIC Magnet Inventory

REGULAR ARC COMPONENTS	
Dipoles	264
Quadrupoles	276
Sextupoles	276
Correctors	276
INSERTION COMPONENTS	
Standard Aperture (8 cm) Magnets	
Dipoles (D5I, D5O, D6, D8, D9)	96
Quadrupoles (Q4-Q9)	144
Trim quadrupoles (@ Q4, Q5, Q6)	72
Sextupoles at Q9	12
Correctors	144
Intermediate Aperture (10 cm) Magnets	
Dipoles (D0)	24
Helical Dipoles	12
Intermediate Aperture (13 cm) Magnets	
Quadrupoles (Q1-Q3)	72
Correctors	72
Large Aperture (18 cm) Magnets	
Dipoles (DX)12	
TOTALS	
Dipoles	408
Quadrupoles	492
Trim quadrupoles	72
Sextupoles	288
Correctors	492
Total magnets	1752

Table 1-2 Magnet Nomenclature - Magnet/Cold Mass

Magnet/Cold Mass	Quan.†	∅(cm)	L(m)	Location		Fabr.	Magnet ID	Coil ID
Dipole	264 (-)	8	9.45	Arc		GAC	DRG###	DCG####
	13 (1)	8	6.92	D5I		GAC	D5I###	DCJ####
	13 (1)	8	8.71	D5O		GAC	D5O###	DCK####
	25 (1)	8	2.95	D6		GAC	D96###	DCH####
	34 (10*)	8	9.45	D8		GAC	DR8###	DCG####
	24 (-)	8	2.95	D9		GAC	D96###	DCH####
	26 (2)	10	3.6	D0		BNL	DRZ###	DCZ####
	12 (2)	10	10.4	IR's		BNL	HRD###	HSD###
	13 (1)	18	3.7	DX		BNL	DRX###	DCX####
Quadrupole	282 (6)	8	1.13	Arc		GAC	QRG###	QCG####
	26 (2)	8	1.83	Q4		GAC	QR4###	QCH####
	25 (1)	8	1.13	Q5		GAC	QRG###	QCG####
	24 (-)	8	1.13	Q6		GAC	QRG###	QCG####
	26 (2)	8	0.95	Q7		GAC	QR7###	QCF####
	25 (1)	8	1.13	Q8		GAC	QRG###	QCG####
	24 (-)	8	1.13	Q9		GAC	QRG###	QCG####
	26 (2)	13	1.44	Q1		BNL	QRI###	QCI####
	26 (2)	13	3.40	Q2		BNL	QRK###	QCK####
	26 (2)	13	2.10	Q3		BNL	QRJ###	QCJ####
Trim quads	78 (6)	8	0.75	Q4,5,6		EEC	QRT###	QCT####
Corrector	100 (4)	8	0.5	Arc + Ins	- Style B	BNL	CRB###	
	136 (4)	8	0.5	Arc + Ins	- Style C	BNL	CRC###	
	78 (-)	8	0.5	Arc + Ins	- Style D	BNL	CRD###	
	78 (-)	8	0.5	Arc + Ins	- Style E	BNL	CRE###	
	40 (4)	8	0.5	Arc + Ins	- Style F	BNL	CRF###	
	13 (1)	13	0.5	Q2 Outer	- Style I	BNL	CRI###	
	13 (1)	13	0.5	Q3 Inner	- Style J	BNL	CRJ###	
	26 (2)	13	0.5	Q3	- Style K	BNL	CRK###	
	13 (1)	13	0.5	Q3 Inner	- Style L	BNL	CRL###	
	13 (1)	13	0.5	Q3 Outer	- Style M	BNL	CRM###	
Sextupole	300 (12)	8	0.75	Arc,Q9		EEC	SRE###	SCE####

† Quantities listed include spares which are listed in parentheses, ( )
* The total of 10 spares are constructed as DR8 type and are interchangeable with DRG type, but not vice versa.

Table 1-3. Magnet Nomenclature - Assembly

Assembly	Quan.†	∅(cm)	L(m)	Location	Fabr.	Magnet ID
CQS	282 (6)	8	3.4	Arc	BNL	CQS###
	12 (-)	8	3.4	Q9	BNL	CQS###
CQT	26 (2)	8	4.1	Q4	BNL	CQ4###
	25 (1)	8	3.4	Q5	BNL	CQ5###
	24 (-)	8	3.4	Q6	BNL	CQ6###
CQ	26 (2)	8	2.5	Q7	BNL	CQ7###
CQ	25 (1)	8	2.6	Q8	BNL	CQ8###
CQBlank	12 (-)	8	3.4	Q9	BNL	CQ9### ††
Dipole	13 (1)	10	4.4	D0	BNL	DIZ###
Q	13 (1)	13	1.9	Q1	BNL	CQ1###
CQ	13 (1)	13	4.4	Q2	BNL	CQ2###
CQC	13 (1)	13	4.0	Q3	BNL	CQ3###
Dummy Assembly	24 (-)	8	2.6	Q4/Q5	BNL	DU4###
	24 (-)	8	6.0	Q6/D6	BNL	DU6###
	24 (-)	8	11.9	Q7/Q8	BNL	DU7###
	24 (-)	8	6.0	Q9/D9	BNL	DU9###

† Quantities listed include spares which are listed in parentheses, ( )
†† 2 assemblies do not contain blank iron